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APPLICATION NUMBER: *60/372,279*
FILING DATE: *April 12, 2002*

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. EL915426647US

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Ionel D.	Jitaru	Tucson, Arizona

☐ Additional inventors are being named on the 1 separately numbered sheets attached hereto

TITLE OF THE INVENTION (500 characters max)

LOW PROFILE MAGNETIC ELEMENT

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages*	7	☐ CD(s), Number	
☒ Drawing(s) *Number of Sheets*	5	☒ Other (specify)	Postcard
☐ Application Data Sheet. See 37 CFR 1.76			

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☐ Applicant claims small entity status. See 37 CFR 1.27.
☒ A check or money order is enclosed to cover the filing fees
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FILING FEE AMOUNT ($): $160.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.
☐ No.
☐ Yes, the name of the U.S. Government agency and the Government contract number are: ______

Respectfully submitted,

SIGNATURE [signature] Date 4/12/02

TYPED or PRINTED NAME Thomas D. MacBlain REGISTRATION NO. *(if appropriate)* 24,583

TELEPHONE 602-530-8088 Docket Number: 14609-0006

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

PROVISIONAL APPLICATION COVER SHEET
Additional Page

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Docket Number	14609-0006

INVENTOR(S)/APPLICANT(S)		
Given Name (first and middle [if any])	**Family or Surname**	**Residence (City and either State or Foreign Country)**
Marco	Davila	Tucson, Arizona

Number 1 of 1

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Docket No. 14609-0006

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Ionel Jitaru, et al.

Serial No.:

Filed: Herewith

For Provisional Patent Application Entitled: LOW PROFILE MAGNETIC ELEMENT

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on

4/12/02
Date

Suzanne Shields
Suzanne Shields

GALLAGHER & KENNEDY, P.A.
2575 East Camelback Road
Phoenix, Arizona 85016-9255
Tel. No. (602) 530-8000
Fax. No. (602) 530-8500

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FEE TRANSMITTAL for FY 2002

Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 160

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Jitaru
Examiner Name	
Group Art Unit	
Attorney Docket No.	14609-0006

METHOD OF PAYMENT (*check all that apply*)

☒ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None

☐ Deposit Account:

Deposit Account Number: 07-0135

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Fee ($)	Small Entity Fee Code	Fee ($)	Fee Description	Fee Paid
101	740	201	370	Utility filing fee	
106	330	206	165	Design filing fee	
107	510	207	255	Plant filing fee	
108	740	208	370	Reissue filing fee	
114	160	214	80	Provisional filing fee	160

SUBTOTAL (1) ($) 160

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below		Fee Paid
Total Claims		-20** =		X		=	
Independent Claims		- 3** =		X		=	
Multiple Dependent						=	

Large Entity Fee Code	Fee ($)	Small Entity Fee Code	Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	84	202	42	Independent claims in excess of 3
104	280	204	140	Multiple dependent claim, if not paid
109	84	209	42	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($)

**or number previously paid, if greater, For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Fee ($)	Small Entity Fee Code	Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	400	216	200	Extension for reply within second month	
117	920	217	460	Extension for reply within third month	
118	1,440	218	720	Extension for reply within fourth month	
128	1,960	228	980	Extension for reply within fifth month	
119	320	219	160	Notice of Appeal	
120	320	220	160	Filing a brief in support of an appeal	
121	280	221	140	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,280	241	640	Petition to revive - unintentional	
142	1,280	242	640	Utility issue fee (or reissue)	
143	460	243	230	Design issue fee	
144	620	244	310	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Processing fee under 37 CFR 1.17(q)	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	740	246	370	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	740	249	370	For each additional invention to be examined (37 CFR § 1.129(b))	
179	740	279	370	Request for Continued Examination (RCE)	
169	900	169	900	Request for expedited examination of a design application	

Other fee (specify) ____________

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($)

SUBMITTED BY				Complete (*if applicable*)	
Name (*Print/Type*)	Thomas D. MacBlain	Registration No. (*Attorney/Agent*)	24,583	Telephone	602-530-8088
Signature				Date	4/12/02

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LOW PROFILE MAGNETIC ELEMENT

Field of the Invention

This invention relates to mechanical construction and its electrical results for planar inductors and planar transformers used in power conversion.

Background of the Invention

The industry demand for increasing power density and lowering the height of power converters imposed the use of planar inductor and planar transformers. The continuous trend for lower voltages and higher current has set new challenges for power magnetic components such as transformers. In order to simplify and control the manufacturing process for power magnetic components, the windings are embedded within multiplayer PCB structures. In such applications the copper thickness is limited. This limitation will exclude applications wherein large currents are processed, which today is the growing trend. One solution to overcome this problem is to split the current and process each section of it before it is provided to the output. Because the power dissipated due to the DC impedance is proportional with the square of the current, splitting the current, for example in two sections will reduce the power dissipation due to the DC impedance four times. Another limitation comes from the semiconductor devices. The trend towards miniaturization has forced the design to use surface mounted, smaller packages for semiconductor devices. These devices will accommodate only a limited die size, i.e., a semiconductor layer or layers of limited size. As a result, such devices provide only a limited current capability.

In Figure 2 is presented a concept of splitting the output current wherein several transformers are employed. The primaries 16, 20 and 24 of the transformers 10, 12 and 14 are in series and the currents in secondaries 18, 22 and 26 are processed in parallel. The windings can be placed in parallel directly or paralleled after the rectifiers. This concept, also described in US patents Nos. 5,990,776 and 6,046,918, offers several advantages. First it splits the output current, which is further processed

(rectified) on parallel paths, before it unites at the output of the converter. By placing several transformers in series the voltage across each primary winding is decreased, and as a result the number of turns in the primary winding can be reduced. A reduced number of turns will decrease the leakage inductance, which is proportional with the square of the number of turns. The use of smaller transformer, and as a result, a smaller magnetic core, will allow a better cooling due to an increased surface area, will decrease the eddy current losses in the magnetic core due to a thinner core, and will prevent the electromagnetic resonant losses associated with very large magnetic cores.

One major drawback of this concept is the fact that the magnetizing inductance is lower, leading to larger magnetizing current and as a result lower efficiency. This is due to the fact that the magnetizing inductance is proportional with the square of number of turns, and the total magnetizing inductance for the magnetic structure from Figure 2 is the summation of all the magnetizing inductances. If there are used "n" independent transformers each of them with a number of turns in primary "N", the magnetizing inductance of the structure is L_m=nKN^2.

In the structure depicted in Figure 3, according to this invention, the "n" number of transformers are linked by the same flux and therefore L_m=K(nN)^2. The result is a much larger magnetizing inductance, lower magnetizing current and, consequently, lower losses.

Summary of the Invention

The invention illustrates a concept of improved utilization of the magnetic core highly suitable for higher current applications. The invention will allow a reduction in the core volume while the current is split to minimize the conduction losses. As a consequence the invention will lead to lower core loss, and lower conduction losses in a transformer structure.

The above and further objects and advantages of the invention will be better understood from the following detailed description of at least one preferred embodiment of the invention, taken in consideration with the accompanying drawings.

Brief Description of the Drawings

Figure 1A is a diagrammatic illustration of the prior art concept wherein two magnetic elements are utilized;

Figure 1B is a diagrammatic illustration of an improvement of the prior art wherein only one magnetic core is employed;

Figure 1C is a diagrammatic illustration of the main embodiment of this invention;

Figure 2 is a schematic illustration of the prior art transformer configuration for splitting the output current;

Figure 3 illustrates one embodiment of a transformer configuration according to the invention for splitting the output current;

Figure 4 illustrates another embodiment of this invention for splitting the output current in four sections;

Figure 5 illustrates another embodiment of this invention for further splitting the output current in "n" sections;

Figure 6 is an exploded view that illustrates an embodiment of the invention that offers a mechanical construction technology employing the present invention; and

Figure 7 is a further exploded view of a further embodiment of a mechanical construction employing the present invention.

Detailed Description

In Figure 3 is depicted the electrical representation of the transformer structure 28, according to this invention. To split the output current, independent secondary windings are used, such as 32, 36...n_s. Typically for high current these secondary windings have only one turn. The primary windings are also split in the same number of sections as the secondary. These sections 30, 34...n_p are closed coupled with their equivalent secondary 32, 36...n_s. In this way we have a close couple between primary and the secondary. The magnetic flux in the magnetic core 150 used by the magnetic

structure 28 links all the winding structures. In Figure 2 is presented the prior art concept wherein independent transformer structures are used for splitting the output current. As mentioned before, in this method the magnetizing current is lower and it leads to a larger magnetizing current and lower efficiency.

In Figure 1 is presented the method of transition from the prior art implementation to the structure claimed in this invention. In Figure 1A are depicted two transformers 42, 44, formed by two E cores or E & I configuration. Each transformer has a one turn winding 64, 66, which surrounds the center leg. In the transformer 42 is presented also the flux through the outer legs 50, 52 of the magnetic core. The flux 100, through the outer leg 50, and the flux 102, through the outer leg 52, unite into the center leg.

In Figure 1B is presented an improvement of the original structure wherein the two transformers merge into only one, 46. There is a one turn winding 68, 70 surrounding each leg 55 and 56. The fluxes 108, 110 generated by the current flowing through the winding 68 and 70 merge into the center leg 58 of the transformer. If the current flowing through the winding 68 is equal to the current flowing through the winding 70, the flux flowing through the center leg 58 is zero.

This leads us to one of the embodiments of this invention depicted in Figure 1C. In Figure 1C, for equal currents flowing through winding 72 and 74 the flux through the center leg is zero, so the next step is to remove the center leg. In this case the transformer 106 is replacing the E core configuration to a C core (or C & I) configuration. One advantage of this is an increase in the winding area, i.e. the area inside the core available for windings. Another advantage is decreasing the core loss due to the decrease of the magnetic core volume.

In Figure 4 is an extension of the concept depicted in Figure 1C to a four winding structure, forming the magnetic structure 76. The windings 116, 114, 120 and 118 are carrying the same current. The flux 112 is flowing through the C cores 186, 180 and through the "I" cores 184, 182. The

structure can be also composed by using only C core configuration, without deviating from the spirit of the invention. The parallel legs of the two C cores can be brought together end to end with the two cores coplanar. This arrangement of the C cores resembles the core of Figure 1C.

In Figure 5 is presented a further extension of the concept depicted in Figure 1C to any number of windings. It illustrates how the concept can be applied to any number of windings multiple of two. The current flowing through the depicted windings 126, 124, 128, 130, 132, 134, nn and mm is equal. This leads to a constant flux flowing through the elements of the magnetic core. The magnetic structure 122 is a generalization of the concept depicted in Figure 1C.

In Figure 6 is presented a mechanical configuration, which offers a practical application of the concepts claimed in this invention. It applies to a planar magnetic using a multilayer circuit board. The windings indicated by the dashed lines 171, 173, 175 and 177, are embedded into the multilayer circuit board 178. Multilayer printed circuit boards having electrically conductive buried windings at least partially encircling core portions that extend through the board are disclosed in U.S. patent No. 5,990,776 of Jitaru, issued November 23, 1999, incorporated herein by reference. The windings here surround the holes 181, 183, 185 and 187. The cylinders 166, 169, 172, 170 made of magnetic material are placed into the holes 181, 183, 185 and 187. Made also of magnetic material, the plates 162, 168, 174 and 176 are secured by conventional means to the tops and bottoms of the cylinders 166, 169, 170, 172 in the relationship shown. The configuration depicted in Figure 6 is a practical implementation of the structure depicted in Figure 4.

Figure 7 illustrates a further implementation of the invention in which the magnetic plates 162, 168, 174 and 176 of Figure 6 are replaced by just two magnetic plates 190 and 192 affixed to the cylinders 166, 169, 172 and 170 at the tops and bottoms of the cylinders.

The advantages of using standard building elements, magnetic plates and magnetic cylinders are numerous. First of all it offers an economical solution in addressing the magnetic design for

different power levels. More elements are employed as a function of the output current requirements. The basic cell uses two plates and two cylinders. From this cell we can extend to as many winding outputs as needed.

The foregoing descriptions of preferred embodiments are exemplary and not intended to limit the invention claimed. Obvious modifications that do not depart from the spirit and scope of the invention as claimed will be apparent to those skilled in the art.

Claims

1. A multilayer printed circuit board of the kind having first and second surfaces on first and second sides of the board and including a transformer with windings defined between layers of the board and a transformer core penetrating the layers of the board and about which the windings are wound; the improvement comprising;

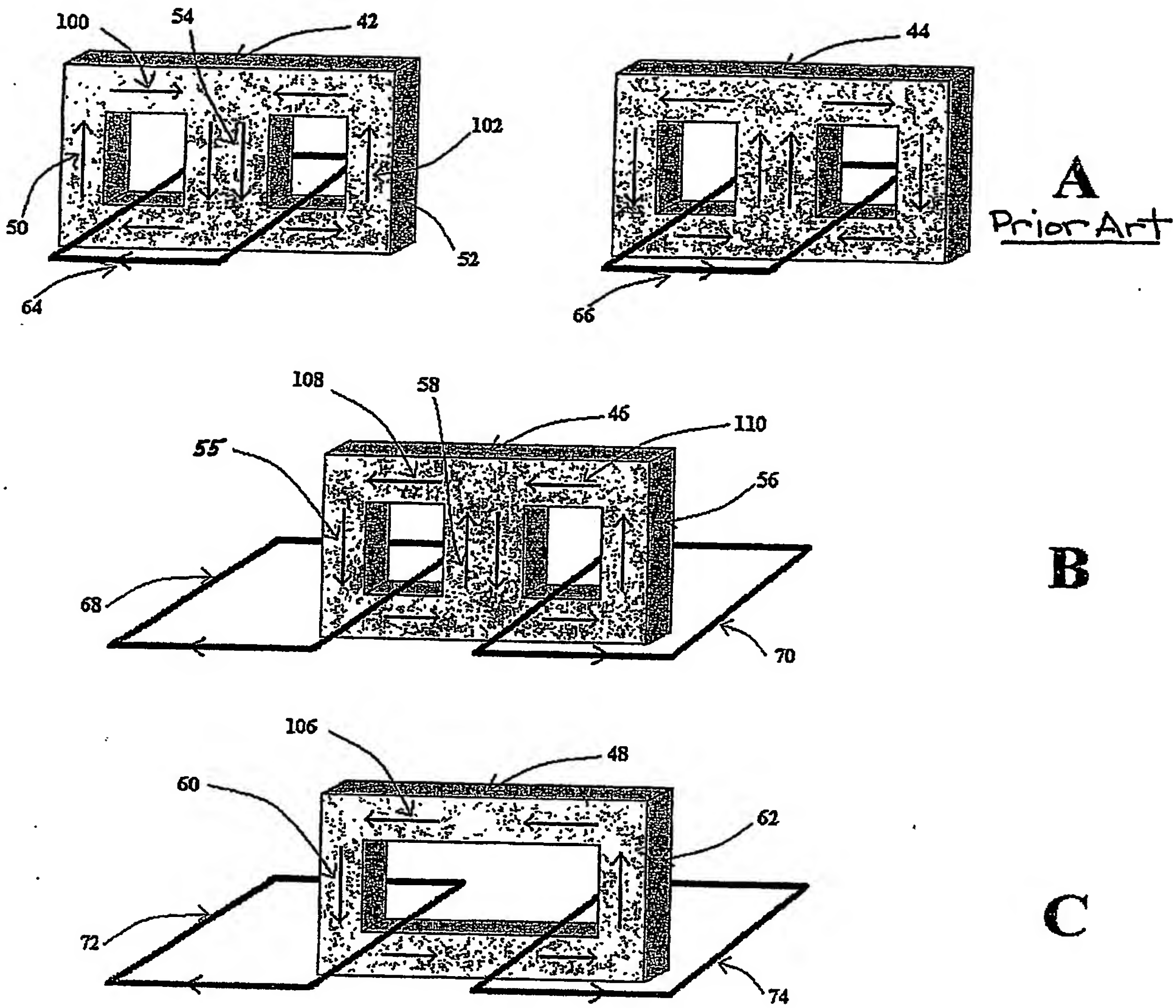
a) a plurality of at least four magnetic core segments extending through the board from the first side to the second side at spaced apart locations;

b) said windings comprising a plurality of at least four windings, each at least partially encircling a separate one of the core segments where the core segments extend through the board;

c) a plurality of substantially planar first magnetic core elements at the first side of the board, each of the first core elements extending between a pair of the magnetic core segments in flux conducting relation thereto such that each core segment at the first side of the board is joined in flux conducting relation to another of the core segments by one of the substantial planar core elements at the first side of the board; and

d) a plurality of substantially planar second magnetic core elements at the second side of the board, each of the second magnetic core elements at the second side of the board extending between a pair of the magnetic core segments in flux conducting relation thereto, each pair of core segments between which a second magnetic core element extends at the second side of the board being in a separate pair of the core segments joined in flux conducting relation by first magnetic core elements at the first side of the board;

the magnetic core elements and core segments forming a continuing, closed magnetic path extending across the first and second faces and through the layers of the board.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Prior Art
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Figure 1

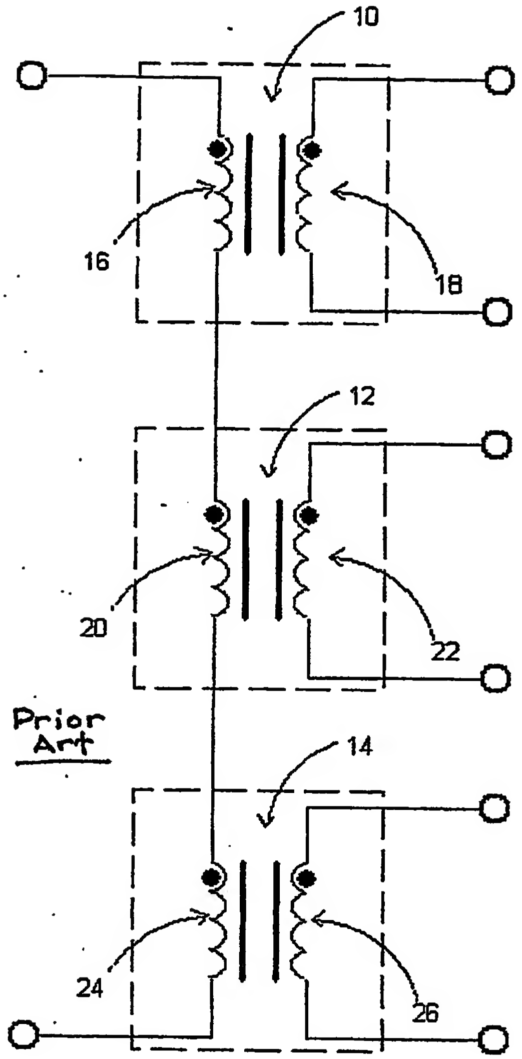

Figure 2

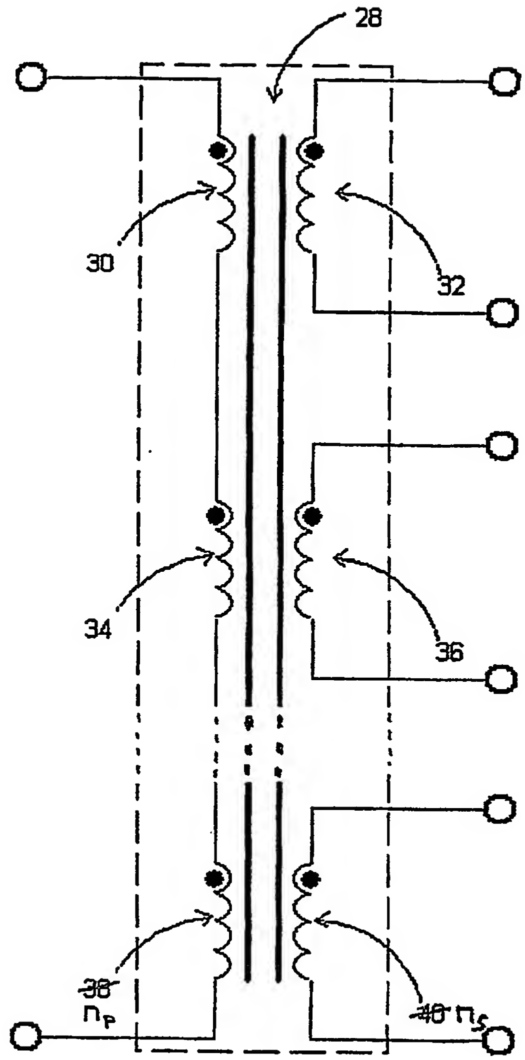

Figure 3

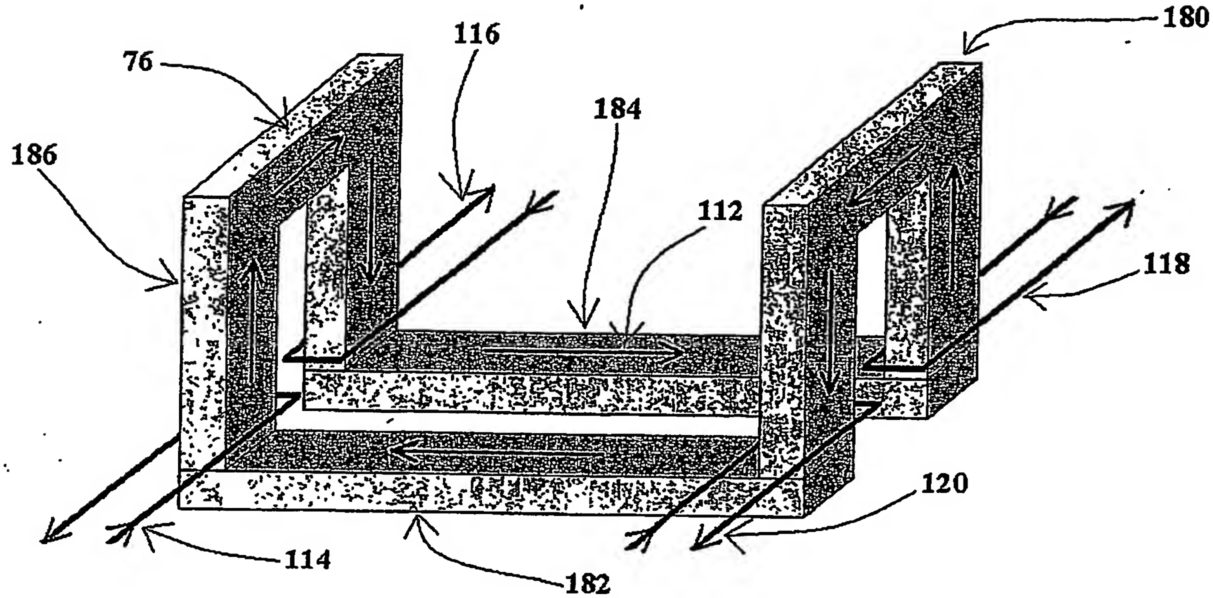

Figure 4

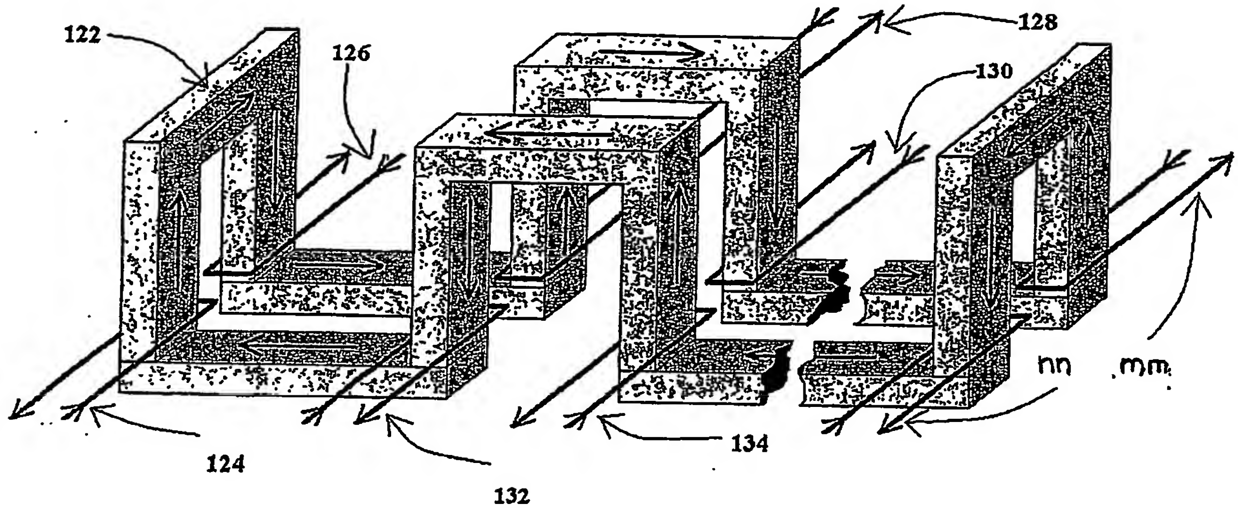

Figure 5

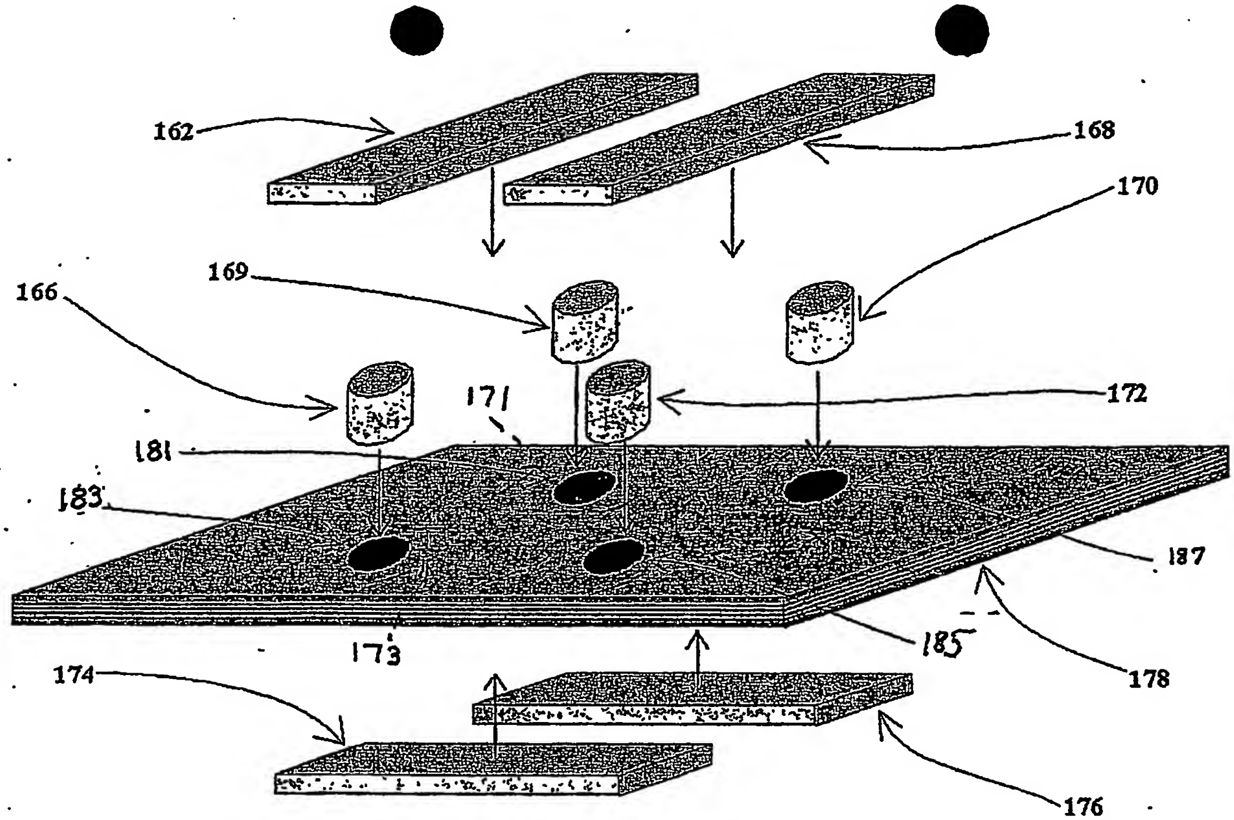

Figure 6

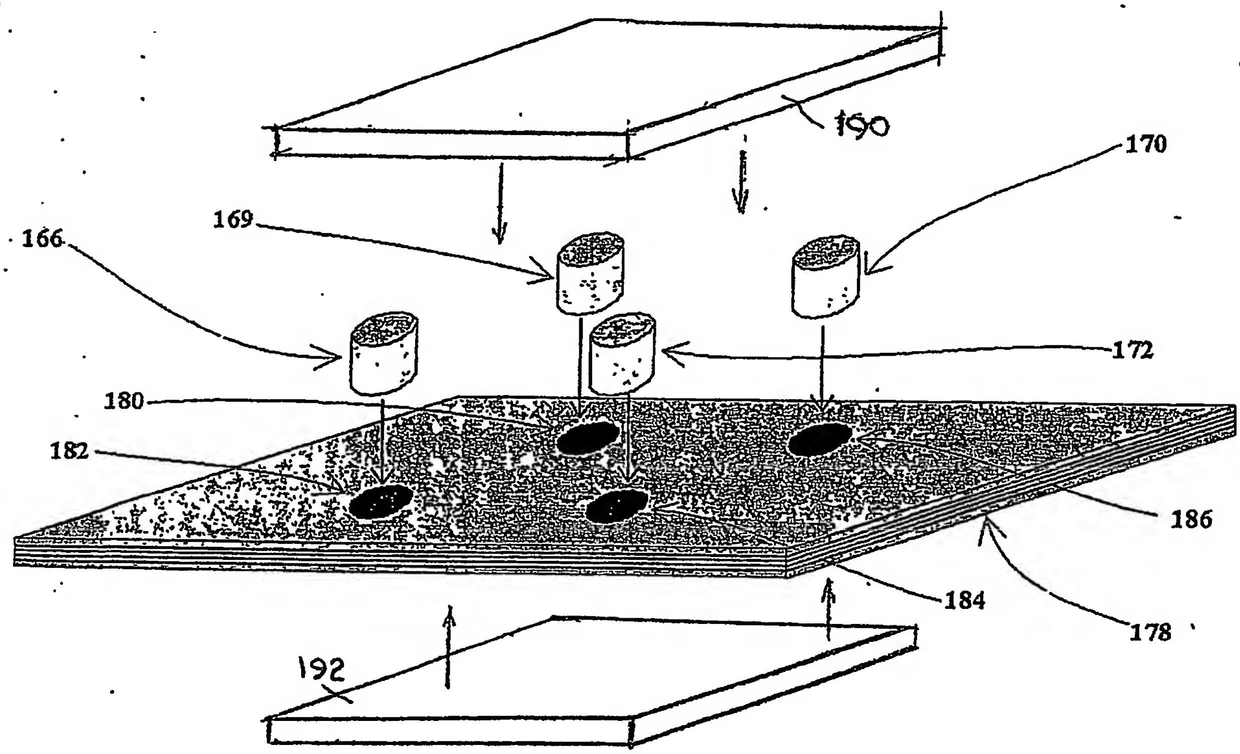

Figure 7

Ionael D. Jitaru
Low Profile Magnetic Element
5/5